

DATA RECONSTRUCTION METHOD AND SYSTEM EMPLOYING THE SAME

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1 BACKGROUND OF THE INVENTION

The present invention relates to a memory for performing access or read/write in parallel with a plurality of independent storage units as a set, and  
5 more particularly to a data reconstruction system and a method used therein which are available in occurrence of a failure.

The technology for controlling discs arranged  
in parallel is disclosed in JP-A-H1-250128 corresponds  
10 to U.S. Patent Application Serial No. 118,785 filed on November 6, 1987 and JP-A-H2-135555.

As for the technology for achieving the large capacity of a memory and the high speed transfer of data, there is known a method in which the data is  
15 <sup>divided</sup> striped into a plurality of data of bit <sup>units</sup> ~~unit~~, ~~byte unit~~ or arbitrary <sup>units</sup> ~~unit~~, with a plurality of storage units as a set, to be stored in the respective storage units, and when the data is to be read out, the plurality of data is simultaneously read out from the respective storage  
20 units. Moreover, in this method, the data to be used for a parity check is produced from the data, <sup>divided</sup> ~~striped up~~ among the storage units to be stored in another storage unit. When the failure occurs in any of the storage units, the data stored in the remaining normal storage  
25 units and the data for the parity check are used to







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- 1 data, there are known the parity data, ~~the~~ Reed-Solomon  
code and error check code (ECC) methods.  
A ~~code and the error check code (ECC).~~

Although the redundancy is provided for the failure of a plurality of storage units, the failure repair in the failure of one storage unit and that in the failure of a plurality of storage units are managed without taking the distinction therebetween into consideration. Therefore, putting emphasis on the repair of the failure, since the processing of the normal access or read/write cannot be performed <sup>in spite</sup> ~~inspite~~ of the failure of one storage unit, there arises a problem in that the efficiency of the processing of the normal access or read/write is reduced. On the other hand, putting emphasis on the normal access or read/write operation, there arises a problem in that the time required for the repair of the failure is not secure during the failure of a plurality of storage units, and as a result, the possibility that the whole system may break down will be increased.

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20 SUMMARY OF THE INVENTION

It is therefore an object of the present invention to minimize the reduction of the processing of the normal access or read/write in the failure, limit the time required for the repair of the failure within a fixed period of time, and ensure the high reliability, with respect to a memory which has the redundancy for the failure of two or more storage units.

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1 It is another object of the present invention  
to provide a data reconstruction system which is capable  
of selecting a suitable data reconstruction method in  
correspondence to the various kinds of conditions  
5 relating to the repair of the failure and carrying out  
the most suitable data reconstruction processing.

It is still another object of the present  
invention to provide a control system which is capable  
of changing the procedure of data reconstruction  
10 processing in correspondence to the change of redundancy  
relating to the number of ECC discs included in a  
plurality of storage units which are arranged in  
parallel to one another.

The above objects of the present invention are  
15 attained by the provision of a memory <sup>including</sup> ~~comprising~~ a  
group of storage units for <sup>dividing</sup> ~~stripping~~ data into a  
plurality of data of bit <sup>units byte units</sup> ~~unit, bite unit~~ or arbitrary  
<sup>units</sup> ~~unit~~ to store therein the <sup>divided</sup> ~~striped~~ data, the plurality of  
independent storage units forming a set; discs for  
20 storing therein ECC data corresponding to the <sup>divided</sup> ~~striped~~  
data; a spare storage unit for storing therein the  
reconstructed data; an <sup>I/O operation</sup> ~~I/O~~-reconstruction control  
circuit for receiving a command relating to I/O issued  
from a host unit to execute processing in accordance  
25 with the command or respond to the host unit; a timer  
for giving the point of failure, an elapsed time during  
the data reconstruction, a unit time and the like; a  
data reconstructing table for the storage unit at fault;



1 and a faulty data reconstructing circuit for performing  
discovery of the faulty data, data reconstruction and an  
operation of writing data to a spare storage disc,  
wherein when a failure occurs in any of the storage  
5 units, the faulty data reconstructing circuit detects  
the failure by an error check to inform the I/O-  
reconstruction control circuit of the failure, and the  
I/O-reconstruction control circuit discriminates a state  
of the failure to select the preferred processing  
10 suitable for the state of the failure out of the  
processing of the normal access or read/write and the  
data reconstruction processing, thereby to execute the  
selected processing, or set the frequency of the  
processing of the normal access or read/write and the  
15 data reconstruction, or the ratio of the ~~processing~~  
~~amount~~.

When the failure occurs in the above memory,  
the redundancy of the memory, the elapsed time during  
the data reconstruction, and the state of the normal  
20 access or read/write processing and the like are  
discriminated, and the data reconstruction processing  
(method) suitable therefor is selected. Therefore, it  
is possible to prevent reduction of the performance of  
the processing of the normal access or read/write and  
25 ensure the high reliability of the memory. More  
specifically, in the case where the number of storage  
units at fault <sup>is less than</sup> ~~has a room for~~ the redundancy of the  
memory, there is selected the data reconstruction



1 processing (method) in which the processing of the  
normal access or read/write is given preference, and the  
faulty data is reconstructed within the remaining period  
of time. Therefore, no load is put on the processing of  
5 the normal access or read/write. On the other hand, in  
the case where there is no <sup>remaining</sup> ~~room in the~~ redundancy, since  
the processing of reconstructing faulty data is given  
preference, it is possible to ensure the reliability for  
the failure of the memory. Moreover, in the case where  
10 there is <sup>some remaining</sup> ~~a room in the~~ redundancy, since the data  
reconstruction processing (method) is changed according  
to the magnitude of the ~~accumulating totals of time~~  
~~which was~~ taken to repair the failure with respect to  
the storage units in which the failure occurred, it is  
15 possible to prevent reduction of the performance of the  
processing of the normal access or read/write and limit  
the time required for the data reconstruction within a  
fixed period of time. Moreover, <sup>a</sup> ~~the~~ time zone, e.g.,  
~~the night~~, having less processing of the normal access or  
20 read/write is selected so that the system can devote  
itself to the data reconstruction. As a result, it is  
possible to reduce the load of the memory in the time  
zone having much processing of the normal access or  
read/write. Moreover, since the frequency of the data  
25 reconstruction processing, or the ratio of the amount of  
data reconstruction <sup>within a unit time</sup> ~~is~~ set according to the magnitude of  
the frequency of the processing of the normal access or



1 read/write, it is possible to carry out the data  
reconstruction processing effectively in a time aspect.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5 Fig. 1 is a flow chart of the processing of  
reconstructing faulty data according to the present  
invention;

Fig. 2 is a block diagram showing the  
arrangement of a memory according to the present  
invention;

10 Fig. 3 is a diagram showing the arrangement of  
a data reconstructing table for a disc at fault of the  
present invention;

Fig. 4 is a flow chart showing the processing  
employed in the memory of Fig. 2;

15 Fig. 5 is a flow chart of a block of selecting  
the data reconstruction processing in Fig. 4;

Fig. 6 is another flow chart of a block of  
selecting the data reconstruction processing in Fig. 4;

20 Fig. 7 is still another flow chart of a block  
of selecting the data reconstruction processing in Fig.  
4;

Fig. 8 is yet another flow chart of a block of  
selecting the data reconstruction processing in Fig. 4;  
and

25 Fig. 9 is a further flow chart of a block of  
selecting the data reconstruction processing in Fig. 4.



1 DESCRIPTION OF THE PREFERRED EMBODIMENTS

The description will hereinafter be given to a flow chart showing the processing of reconstructing faulty data of Fig. 1.

- 5 It is assumed that a failure occurs in a memory or a motor (Step 10). In this connection, this failure is detected by the check of an error check code or by the check of the deviation of a motor driving voltage from a predetermined range. First, it is judged
- 10 whether or not the failure thus occurred is repairable (Step 20). If not, then, the data reconstruction processing is completed. This results in the data loss (Step 30). If so, it is judged on the basis of the redundancy of the memory, the elapsed time of the data
- 15 reconstruction and the processing state of the processing of the normal access or read/write whether or not it is a state in which the system should devote itself to the data reconstruction (Step 40). If a request to process the normal processing such as access
- 20 or read/write is issued from a host unit under the condition in which there is a sufficient <sup>remaining redundancy</sup> ~~room~~ and the urgency of the reconstruction is low, the data reconstruction processing is stopped and the normal processing such as access or read/write is given
- 25 preference. Then, the data reconstruction processing is performed within the remaining period of time, and the processing of access or read/write during the data reconstruction is cancelled or queued (Step 50).



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- 1 Conversely, if there is no <sup>remaining red</sup> room and the urgency of the reconstruction is high, the data reconstruction processing is given preference, and all of the normal processing such as access or read/write is cancelled or
- 5 queued (Step 60). Moreover, in the case of the intermediate state in which there are some combinations between the urgency of the data reconstruction and the significance of the normal processing such as access or read/write, the data reconstruction processing
- 10 corresponding to the individual conditions is previously prepared in the form of programs. Then, when the conditions are changed, <sup>a</sup> ~~it can proceed to the~~ suitable processing <sup>can be performed</sup> by replacing an old program with a new one (Step 70). Next, when the data reconstruction
- 15 processing is completed or interrupted, it is checked whether or not the data reconstruction processing still remains (Step 80). After all of the data reconstruction processing has been completed, the memory returns to the normal <sup>state (step 90).</sup> state. If the data reconstruction processing
- 20 still remains, the flow returns to Step 20 and the above <sup>steps</sup> steps will be repeated until the data reconstruction is completed.

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Next, ~~the description will be given to~~ a block diagram showing the arrangement of an embodiment of the present invention <sup>will be described with reference to</sup> of Fig. 2.

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In Fig. 2, the reference numeral 150 designates an I/O-reconstruction control circuit which receives a command relating to <sup>an I/O operation</sup> ~~I/O~~ issued from the host



1 unit to carry out the processing according to the  
command or respond to the host unit. Further, when <sup>a</sup> the  
failure <sup>has occurred</sup> ~~is occurring~~ in any of the storage units, the  
circuit 150 serves to select a suitable data reconstruc-  
5 tion method on the basis of the number of discs during  
the reconstruction, the time taken to reconstruct the  
faulty data, the frequency of the data reconstruction,  
or the amount of the data <sup>reconstruction within a unit time</sup> ~~reconstruction~~, and the like.  
There is connected to the individual storage units a  
10 monitor 155 which monitors <sup>whether</sup> ~~that~~ after the power source  
for driving the storage units is activated, the driving  
voltage is in a predetermined range, and feeds a pseudo-  
instruction for reading out the data previously stored  
in a predetermined location to the storage units <sup>which are entering</sup> ~~getting~~  
15 <sup>an monitors</sup> ~~into~~ the running state <sup>to monitor</sup> the responses sent  
therefrom. The reference numeral 154 designates a data  
reconstructing table for the storage unit at fault of  
which details will be described <sup>below with respect</sup> ~~on referring~~ to Fig. 3.  
The reference numeral 152 designates a clock or timer  
20 for obtaining the point of failure by giving the time of  
day and obtaining the elapsed time during the re-  
construction and the unit time by a certain method.  
Then, the data reconstruction method can be changed <sup>based on</sup> ~~with~~  
the time measured by the timer as one condition. The  
25 reference numeral 156 designates a circuit for re-  
constructing faulty data which performs the discovery of  
the faulty data, the data reconstruction and the <sup>writing</sup> ~~write~~  
of the data to a spare storage disc. Moreover, the



1 circuit 156 reads out the data from all of the discs  
except the disc at fault, reconstructs the faulty data  
using the data thus read out, and transfers the  
reconstructed data to the host unit and writes it to the  
5 spare storage disc. The reference numerals <sup>158, 160, 162, 164, 166, and</sup> ~~158 to 168~~  
designate a group of data discs for storing therein the  
<sup>divided</sup> ~~striped~~ data. Although <sup>six data</sup> ~~the six~~ discs are shown as the  
~~data discs~~ in Fig. 2, the number thereof is generally  
arbitrary. The reference numerals 170 and 172 designate  
10 discs which store therein ~~the~~ ECC data corresponding to  
the <sup>divided</sup> ~~striped~~ six data which is stored in the <sup>six data discs 158, 160, 162, 164, 166, and</sup> ~~discs 158 to~~  
168. When the failure occurs, the faulty data is  
reconstructed using the ECC data and the normal data  
among the ~~data 158 to 168~~. In this connection, the  
15 redundancy <sup>of the memory</sup> ~~which the memory has~~ corresponds to the  
number of ECC discs with respect to the number of discs  
up to a certain number. But, in the case where the  
<sup>more than a certain number of the discs break down</sup> ~~discs break down of which number is more than that~~  
~~certain number~~, it is impossible to reconstruct the  
20 faulty data. This results in the data loss. Fig. 2  
shows that ~~even~~ when the number of ECC <sup>discs</sup> ~~data~~ is two,  
<sup>When</sup> ~~i.e.~~, the two data discs break down, the faulty data can  
be reconstructed. However, since there is generally  
known <sup>an</sup> ~~the~~ ECC production method which <sup>can compensate for</sup> ~~stands up to the~~  
25 failure of two or more discs, the number of faulty discs  
which does not result in the data loss, i.e., ~~the~~  
redundancy, can be increased. The ECC production is  
concretely realized using the Reed-Solomon <sup>code</sup> ~~code~~. The







1 table 154 (Step 102). Subsequently, the circuit 150  
checks whether or not that failure is a failure which  
occurred in a new disc (Step 104). If so, the circuit  
150 instructs the circuit 156 to write the following  
5 initial values <sup>in</sup> ~~to~~ the columns of interest in the data  
reconstructing table 154 of Fig. 3. That is, the  
circuit 156 writes the identification number SPARE 1 of  
the spare disc 174 <sup>in</sup> ~~to~~ the column of the spare storage  
unit in the data reconstructing table 154, and writes  
10 the identification number #2 of the data disc 162 at  
fault <sup>in</sup> ~~to~~ the column of the storage unit at fault. Next,  
the circuit 156 writes the point of failure read out  
from the timer 152 <sup>in</sup> ~~to~~ the column of the point of  
failure, and writes the failure occurrence address in  
15 the faulty disc 162 <sup>in</sup> ~~to~~ the column of <sup>the sector or address of the failure</sup> ~~address~~. Finally,  
the circuit 156 initializes the reconstruction judgement  
flag of each address (Step 106). If that failure is not  
a new one, the processing of Step 106 is not executed,  
but the processing proceeds to the subsequent <sup>step</sup> ~~step~~. In  
20 the subsequent <sup>step</sup> ~~step~~, the circuit 150 discriminates the  
state of the failure, selects either the processing of  
the normal access or read/write, or the data  
reconstruction processing which is suitable for the  
state of the failure, and executes the selected  
25 processing (Step 108). The details of this Step 108  
will be described <sup>below with reference</sup> ~~on referring to~~ Fig. 5 to Fig. 9.  
Next, when the data reconstruction processing is  
completed or interrupted, it is checked whether or not



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1 the data reconstruction processing still remains (Step 110). When all of the data reconstruction processing is completed, the memory returns to the normal <sup>state (Step 112)</sup> state. When the data reconstruction processing still remains, the processing returns to Step 102, <sup>and the above steps</sup> ~~then, the above steps~~ <sup>are</sup> ~~will be~~ repeated until all of the data reconstruction processing is completed. <sup>when</sup> ~~Even if~~ any data reconstruction method is chosen, the circuit 156 monitors the continuation or completion of the data reconstruction processing. In the case where, <sup>a</sup> the subsequent failure occurs when the data reconstruction of interest has not yet been completed, the circuit 156 starts performing the processing in the same manner as described above (Step 102). Then, <sup>is</sup> ~~in~~ the case where the number of 15 faulty discs, <sup>for</sup> ~~of~~ which data reconstruction is not completed exceeds the redundancy of the memory, since the data reconstruction is impossible, the circuit 150 informs the host unit of, <sup>a</sup> ~~the~~ data loss (Step 114). If the data reconstruction processing is completed, the 20 unnecessary data in the data reconstructing table 154 is erased and the memory returns to the normal state (Step 112). The address in the table 154 may <sup>be in</sup> ~~have~~ a track ~~units, sector units, word units, or any other units~~ ~~unit, a sector unit, a word unit or any unit.~~

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Next, ~~the description will be given to~~ Step 25 108 of Fig. 4 <sup>will be described with reference</sup> ~~on referring to~~ Fig. 5.

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In Fig. 5, the I/O-reconstruction control circuit 150 counts the number of discs, <sup>for</sup> ~~of~~ which data reconstruction <sup>has not been</sup> ~~is not~~ completed by referring to the data



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1 reconstructing table 154, and compares the number of  
faulty discs with <sup>a</sup>the threshold (Step 120). If the  
number of faulty discs is less than the threshold which  
is previously set to a value less than <sup>or equal to</sup> or equal to the  
5 redundancy, the circuit 150 judges that there <sup>Some remaining</sup> ~~is a room~~  
~~in the~~ redundancy, gives the processing of access or  
read/write preference, and performs the processing of  
reconstructing faulty data within the remaining period  
of time. All of the processing such as access or  
10 read/write during the reconstruction waits, i.e., it is  
cancelled or queued (Step 122). On the other hand, if  
the number of faulty discs is more than the threshold,  
the circuit 150 judges that <sup>there is no remaining redundancy</sup> ~~the redundancy has no room~~,  
gives the ~~data~~ reconstruction processing preference, and  
15 cancels or queues all of the normal processing such as  
access or read/write (Step 124).

The reconstruction is performed <sup>on the basis of</sup> ~~with~~ a unit,  
such as 1 track, in which the repair and the storage are  
completed <sup>in</sup> ~~for~~ a relatively short period of time. After  
20 the completion of the reconstruction, the memory is  
opened for the normal processing. But, when the  
instruction of the processing of access or read/write is  
issued from the host unit during the reconstruction, the  
data reconstruction work is stopped immediately, and  
25 then the memory is opened for the processing of access  
or read/write. In the case where during the processing  
of access or read/write, ~~the~~ data which has not yet been  
reconstructed is read out, the faulty data is then

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1 reconstructed using the ECC data and the normal data  
which was used when producing the ECC data, and the  
reconstructed data is sent to the host unit. At the  
same time, the reconstructed data is stored in the spare  
5 disc and the reconstruction judgement flag of the  
address column of interest in the data reconstructing  
table 154 is set to <sup>indicate</sup> ~~the~~ completion of the construc-  
tion. If this flag is set to <sup>indicate</sup> ~~the~~ completion of the  
reconstruction, the subsequent access to this data is  
10 performed with the spare disc. In the case of <sup>writing</sup> ~~write of~~  
data, after the ECC data has been produced, <sup>which would normally</sup> ~~the data to~~  
be stored in the faulty disc is stored in the spare  
disc, and then the reconstruction judgement flag is set  
to <sup>indicate</sup> ~~the~~ completion of the reconstruction.

Since in the example of Fig. 2, the redundancy is two, it is proper that the threshold is necessarily set to 1. However, in the case where the Reed-Solomon <sup>code</sup> ~~code~~ capable of correcting <sup>errors in</sup> ~~the multiplex dissipation~~ ~~with~~ two or more discs is used, the threshold may <sup>be</sup> ~~have~~ an arbitrary <sup>integer</sup> ~~integral~~ number less than or equal to the redundancy. Those values are previously set in the table 157.

Since the I/O-reconstruction control circuit 150 stores the address of the <sup>last</sup><sub>1</sub> data which was re-constructed, ~~at the last time~~, the data reconstruction is <sup>Continued</sup><sub>1</sub> ~~performed~~ from the subsequent address. In the reconstruction, the address of the <sup>last</sup><sub>1</sub> data which was reconstructed ~~at the last time~~ and previously stored is used. Then,



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1 when the flag is not set in the data reconstructing  
table <sup>154, thus indicating that</sup> ~~154~~ and thus the data reconstruction is not  
completed with respect to the subsequent address, the  
data <sup>at</sup> ~~of~~ that address is reconstructed. The reconstruc-  
5 tion of the data is performed in such a way that the ECC  
data and the normal data which was used to produce the  
ECC data from the normal discs are read out and the  
circuit 156 for reconstructing faulty data is used. The  
reconstructed data is written <sup>in</sup> ~~to~~ the spare disc and the  
10 flag in the data reconstructing table 154 is set to <sup>indicate</sup> ~~the~~  
completion of the data reconstruction. Then, the  
reconstructed data in the spare disc <sup>can</sup> ~~will~~ be accessed.  
The address of the reconstructed data is stored in the  
circuit 156, and the processing by the circuit 156  
15 proceeds to the subsequent data reconstruction  
processing.

In the embodiment of Fig. 5, when the number  
of faulty discs is less than or equal to the threshold,  
the processing of the normal access or read/write takes  
20 precedence over the data reconstruction. Therefore, it  
is possible to reduce degradation of the performance of  
access or read/write of the memory. Moreover, since in  
a state in which the system devotes itself to the data  
reconstruction, the reconstruction can be performed <sup>in a</sup> ~~for~~  
25 ~~the~~ short period of time, it is possible to maintain the  
reliability of the memory.

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In the above embodiments, the data reconstruc-  
tion method is selected by paying attention to only the



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1 number of faulty discs. However, the elapsed time taken to reconstruct the faulty data, <sup>can</sup> ~~can be~~, in addition to the number of faulty discs, <sup>be</sup> included in the conditions.

Next, <sup>another example of</sup> ~~the description will be given to~~ Step 5 108 of Fig. 4, <sup>will be described with reference</sup> ~~on referring to~~ Fig. 6.

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In Fig. 6, the I/O-reconstruction control circuit 150 counts the number of discs, <sup>for</sup> ~~of~~ which reconstruction is not yet completed by referring to the data reconstructing table 154, and compares the number  
10 of faulty discs with, <sup>9</sup> ~~the~~ threshold (Step 130). If that number is less than or equal to the threshold, then, the circuit 150 reads the present time from the timer 152, and compares the time taken to reconstruct the faulty data, which can be calculated from the present time and  
15 the point of failure in the data reconstructing table 154, with a predetermined limit time (Step 132). Then, if the reconstruction time is less than the predetermined limit time, it is considered that ~~there is a room~~ <sup>reconstruction can be deferred</sup> ~~for the data reconstruction.~~ Therefore, the circuit 150  
20 instructs the circuit 156 for reconstructing faulty data to give the processing of the normal access or read/write preference, reconstruct the data in the faulty discs within the remaining period of time, and store the reconstructed data in the spare disc. The request to  
25 perform the processing of access or read/write issued from the host unit during the reconstruction is cancelled or queued (Step 134). If the number of faulty discs is more than the threshold, or the ~~difference~~



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1 ~~reconstruction time is~~  
1 ~~between the present time and the point of failure is~~  
more than the predetermined limit time, it is considered  
that the data reconstruction cannot be deferred  
that there is no room for the data reconstruction.

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Therefore, the circuit 150 cancels or queues the command  
5 of the normal access or read/write issued from the host  
unit and instructs the circuit 156 to give the data  
reconstruction preference (Step 136).

In the embodiment of Fig. 6, when the time  
taken to reconstruct the faulty data exceeds the limit  
10 time, the system devotes itself to the processing of  
reconstructing faulty data. Therefore, it is possible  
to limit the reconstruction time within <sup>9</sup>the fixed period  
of time and improve the reliability of the memory.

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15 ~~Next, the description will be given to Step~~  
108 of Fig. 4, <sup>another example of</sup>  
<sup>will be described with reference</sup>  
~~on referring to Fig. 7.~~

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In Fig. 7, the I/O-reconstruction control  
circuit 150 obtains the present time from the timer 152  
and judges whether or not that time is <sup>in</sup><sub>1</sub> a time zone  
having much processing of the normal access or read/  
20 write (Step 140). If not, the circuit 150 cancels or  
queues the command of the normal access or read/write  
issued from the host unit, and instructs the circuit 156  
for reconstructing faulty data to give the data re-  
construction preference. Moreover, even if that time is  
25 ~~the time zone~~, when the number of faulty discs of Step  
142 exceeds the threshold, similarly, the data re-  
construction processing is given preference (Step 146).  
Only when <sup>time is in a</sup><sub>1</sub> <sup>having</sup><sub>1</sub> that time zone has much processing of the



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1 normal access or read/write and the number of faulty  
discs is less than or equal to the threshold<sup>is</sup>, the  
processing of the normal access or read/write is given  
preference and the data reconstruction ~~is~~ performed <sup>within</sup> for  
5 the remaining period of time (Step 144).

In the embodiment of Fig. 7, when it is  
previously known that the method of using the memory  
depends on the time zone, the data reconstruction  
processing can be assigned to the time zone having less  
10 processing of access or read/write. Therefore, the data  
reconstruction processing can be smoothly carried out  
without the processing of access or read/write hindering  
the data reconstruction processing.

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In the above-mentioned <sup>examples</sup> ~~embodiments~~ of Fig. 5  
15 to Fig. 7, there are provided two kinds of data reconst-  
ruction processing in which the reconstruction or the  
processing of access or read/write is given preference.  
However, the kind of data reconstruction processing may  
be increased in correspondence to the circumstances.

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20 Next, <sup>another example of</sup> ~~the description will be given to~~ Step  
108 of Fig. 4 <sup>will be described with reference</sup> ~~on referring to~~ Fig. 8.

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In Fig. 8, when the number of faulty discs  
exceeds the threshold in Step 180, the data reconstruc-  
tion processing is given preference and the processing  
25 of the normal access or read/write is stopped (Step  
188). When the number of faulty discs is less than or  
equal to the threshold, and <sup>the time is not in</sup> ~~it is not~~ the time zone  
having much processing of the normal access or



1 read/write in Step 182, only the read processing is  
performed and the data reconstruction processing is  
given preference for the remaining period of time (Step  
186). When the number of faulty discs is less than or  
5 equal to the threshold and <sup>the time is in</sup> ~~it is~~ the time zone having  
much processing of the normal access or read/write, the  
processing of the normal access or read/write is given  
preference and the data reconstruction processing is  
performed within the remaining period of time (Step  
10 184).

In the embodiment of Fig. 8, when the number  
of faulty discs is less than or equal to the threshold,  
but <sup>the time is in</sup> ~~it is~~ the time zone having less processing of the  
normal access or read/write, especially, the time zone  
15 having only the read processing, the read processing is  
<sup>preferentially</sup> ~~exceptionally~~ allowed to be performed, whereby it is  
possible to reduce degradation of the performance of the  
memory without hindering the data reconstruction  
processing.

20 Next, <sup>another example of</sup> ~~the description will be given to Step~~  
108 of Fig. 4 <sup>will be described with reference</sup> ~~on referring to Fig. 9.~~

In Fig. 9, when the number of faulty discs  
exceeds the threshold in Step 190, or the number of  
faulty discs is less than or equal to the threshold in  
25 Step 190 and the <sup>time taken to reconstruct the faulty data</sup> ~~accumulating totals of the data~~  
reconstruction time exceeds the limit time in Step 192,  
the data reconstruction processing is given preference  
and the processing of the normal access or read/write is



1 stopped (Step 202). When the number of faulty discs is  
less than or equal to the threshold and the ~~accumulating~~  
*time taken to reconstruct the faulty data*  
~~totals of the data reconstruction time~~ is less than the  
limit time, the I/O-reconstruction control circuit 150  
5 reads <sup>a</sup> the unit time from the timer 152, and compares the  
frequency of the processing of the normal access or  
read/write within that unit time with <sup>a</sup> the predetermined  
threshold (Step 194). When the frequency of the  
processing of the normal access or read/write is more  
10 than the threshold, it is considered that the ~~accumu-~~  
~~lation is within the limit time and there is a room for~~  
the data <sup>reconstruction can be deferred</sup> ~~reconstruction~~. Therefore, the processing of  
the normal access or read/write is given preference and  
the data reconstruction processing is performed within  
15 the remaining period of time (Step 196). On the other  
hand, when the frequency of the processing of the normal  
access or read/write is less than the threshold, ~~and the~~  
frequency thereof <sup>may have any magnitude</sup> ~~is limitlessly~~ near or far from the  
threshold, <sup>and thus</sup> the frequency changes in magnitude. There-  
20 fore, the frequency of the data reconstruction proces-  
sing or the ratio of the amount of <sup>the</sup> data reconstruction  
within the unit time is dynamically set according to the  
magnitude of the frequency of the processing of the  
normal access or read/write (Step 198). Then, the data  
25 reconstruction processing is carried out according to  
the frequency of the data reconstruction processing or  
the ratio of the amount of the data reconstruction <sup>within the unit time</sup> ~~thus~~  
set (Step 200).



1 In the embodiment of Fig. 9, the frequency of  
the data reconstruction processing or the ratio of the  
amount of the data reconstruction <sup>within the unit time</sup> is set according to  
the magnitude of the frequency of the processing of the  
5 normal access or read/write. Therefore, the data re-  
construction processing <sup>can</sup> ~~will~~ be carried out effectively  
in a time aspect.

Although <sup>a</sup> ~~the~~ magnetic disc is <sup>used</sup> ~~given~~ as the  
storage unit in the above-mentioned embodiments, the  
10 present invention is not limited thereto or thereby.  
That is, alternatively, an optical disc, a floppy disc,  
or a semiconductor memory may be used as the storage  
unit.

Moreover, as the conditions for selecting the  
15 data reconstruction method, instead of the above embodi-  
ments, the job contents of the host unit, the signifi-  
cance of the file in the memory, and the like may be  
used as the conditions. The combination of those  
conditions and the data reconstruction method allows the  
20 flexible data reconstruction processing to be performed.

According to the above embodiments, when the  
number of storage units at fault is less than the  
redundancy of the memory, the processing of access or  
read/write takes precedence over the data reconstruction  
25 processing. Therefore, the load of the memory is not  
increased so that it is possible to reduce degradation  
of the response performance of the memory in the  
processing of access or read/write to the utmost.



A 1 Moreover, since when <sup>the remaining</sup> ~~a room of the~~ redundancy becomes  
small, the processing of access or read/write is  
automatically stopped and the data reconstruction  
processing is given preference, the reliability of the  
5 memory is not reduced. Further, since the data reconst-  
ruction processing method is changed according to the  
<sup>time taken to reconstruct the faulty data</sup>  
~~accumulating totals of the data reconstruction proces-~~  
sing time of the storage units at fault, it is possible  
to realize <sup>a</sup> ~~the~~ memory of higher reliability. Moreover,  
10 since the frequency of the data reconstruction proces-  
sing or the ratio of the amount of the data reconstruc-  
<sup>within the unit time</sup>  
tion <sup>1</sup> is set according to the magnitude of the frequency  
of the processing of access or read/write, it is  
possible to carry out the data reconstruction processing  
15 effectively in a time aspect.